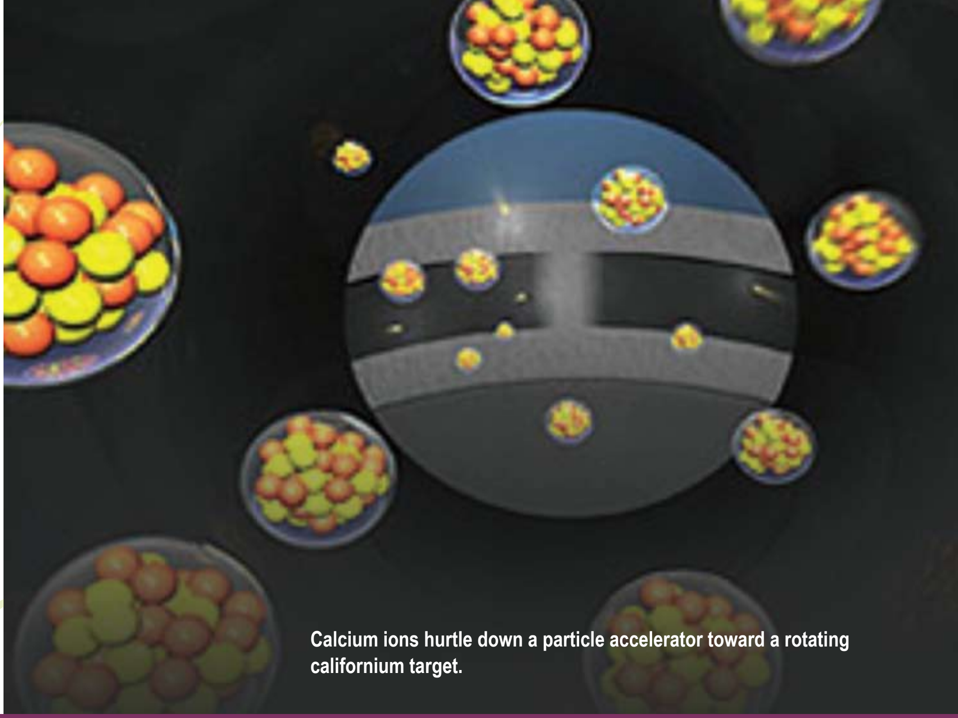
An LDRD Success Story

National Nuclear Security Administration's
Lawrence Livermore National Laboratory



Calcium ions hurtle down a particle accelerator toward a rotating californium target.

In Search of New Superheavy Elements

Atomic Creation

Lawrence Livermore researchers are creating new chemical elements—the latest by fusing an atom of calcium-48 with californium-249. Discovery of the latest element with an atomic number of 118, the heaviest ever created, is part of LDRD projects investigating properties of heavy elements.

Why Create New Elements?

Synthesizing new elements and measuring their properties support national security by furthering knowledge about the limits of nuclear stability and the fission process, important for assessing nuclear device performance and countering proliferant and terrorist activities involving nuclear materials. In addition, this research helps clarify issues related to nuclear power production and safe disposal of radioactive materials.

The discovery of element 118 represents one more step toward the ''island of stability'' that theorists have predicted in heavier regions of the periodic table—isotopes with relatively stable and longer half-lives. These isotopes would form an island of stability in the "sea" of highly unstable isotopes that exist beyond the natural elements.

The most stable atoms contain ''magic numbers'' of protons that produce closed, or complete, shells. Researchers predicted decades ago that there could be another closed shell, with magic numbers of 114 protons and 184 neutrons. The fact that element 118 did not undergo fission immediately, however, was unexpected and suggests that the island of stability is larger than predicted.

Applications for the newest element have not yet been pursued. However, heavy elements have been used in smoke detectors, medical diagnostic aids, and neutron radiography, as well as spectrometers for analyzing the geology on Mars.

Mapping the Island of Stability

- In 1995, the Laboratory Directed Research and Development Program (LDRD) funded a collaboration with the Joint Institute for Nuclear Research in Dubna, Russia to examine nuclear stability in heavy nuclei. Livermore has provided critical hardware, special nuclear materials, chemical and nuclear analytical techniques, and parallel data analysis.

- In 1998, another LDRD-funded project sought to discover and characterize very heavy isotopes around atomic number 114, a theoretically stable nuclear shell. Livermore supplied the plutonium-244 target, which was bombarded with calcium-48.

- In 1999, researchers performed two long irradiations and isolated signatures of the decays of two atoms of element 114 with a half-life of 30 seconds, constituting discovery of that element. The first observations of element 116 followed in 2000. Consistent data utilizing two different targets verified increased stability of nuclides in this region.

- Discovery of new superheavy elements 113 and 115 in 2004 was reported on the front page of the *New York Times*. Discoveries were based on several counts obtained during months of target bombardment.

- For a third LDRD project in 2004, researchers proposed to further clarify the far edge of the island of stability. In 2005, they produced three atoms of element 118, expected to be a noble gas beneath radon on the periodic table. The search for element 120 will further map what is being discovered as a large, rather flat island of stability.

- Extending the heavy end of the nuclides chart has been one of the most significant events of nuclear chemistry and physics in the last 50 years. Based on results published widely in both scientific and mainstream media and the number of requests for talks at international conferences, it is apparent that Livermore has established itself as a premier nuclear and radiochemistry facility.

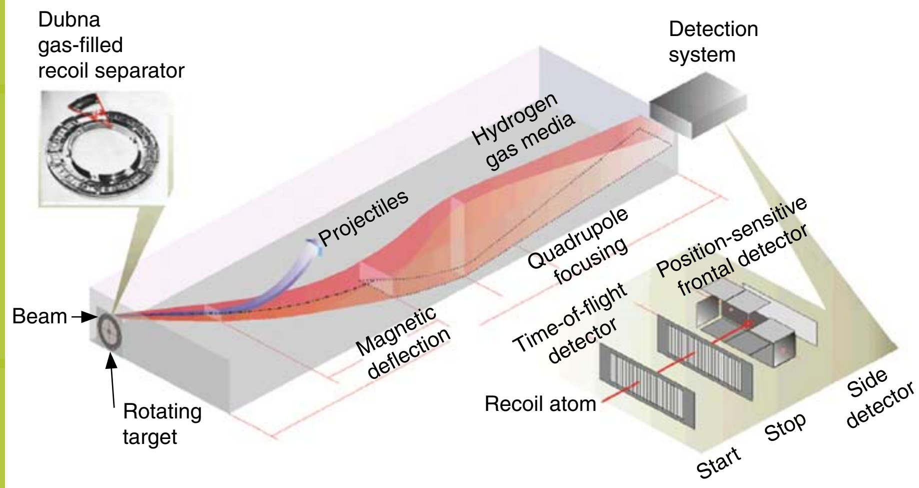
About LDRD

The Laboratory Directed Research and Development Program (LDRD) is LLNL's primary mechanism for funding cutting-edge R&D to enhance the Laboratory's scientific vitality. Established by Congress in 1991, LDRD collects funds from sponsored research and competitively awards those funds to forward-thinking, potentially high-payoff projects aligned with Laboratory missions.

Lawrence Livermore scientists have collaborated with the Russian Joint Institute for Nuclear Research in the discovery of five new heavy elements. Here, researchers perform chemical separations on reaction products produced in the institute's 4-meter cyclotron. Livermore has participated in the construction of a new mass separator expected to increase isotope production and enable further chemical and physical measurements.

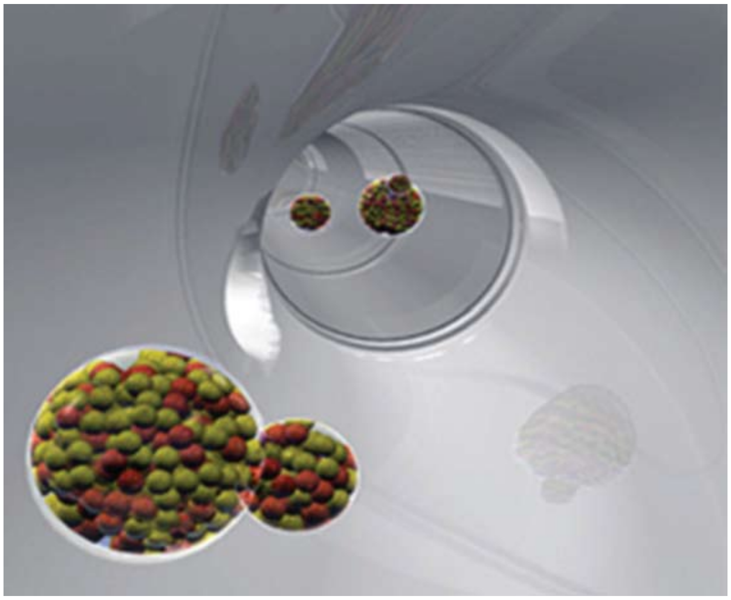
Acceleration and Separation

Accelerated to nearly 30,000 kilometers per second, calcium-48 bombards a spinning californium-249 target. Californium, with 98 protons, fuses with the 20-proton calcium, creating a new 118-proton element. An atom of the newly created element enters a gas-filled recoil separator (shown at right), where it reaches an equilibrium state by picking up electrons from hydrogen that fills the chamber. A magnetic field allows only atoms with a matching charge state to pass to a detector, which is key to proving the new element's fleeting existence. An atom passes through a time-of-flight counter that detects its speed, then moves into the detector box and implants itself in a silicon wall. The counter sends a signal that helps identify new and heavier atoms, which travel more slowly than by-products.



Confirming Its Existence

The newly created element 118, shown here traveling to the detector, undergoes an alpha decay almost immediately, ejecting two protons and two neutrons from its nucleus to create element 116. Element 116, in turn, decays to element 114, which then either undergoes fission or a third decay to element 112. Scientists do not see element 118 itself—only the unique and distinctive alpha decays that prove it existed. Because each decay product is so heavy, they do not travel far between decays, and the detector's signal shows each one. Only alpha decays within a particular time frame and with certain energy signatures can possibly be emitted from element 118.



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